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NATIONAL DAM SAFETY PROGRAM. SUNNEN DAM (MO 30111). MISSISSIPPI--ETC(U)
SEP 78 M J KLOSTERMAN, P S EYDMANN, T F WOLFE

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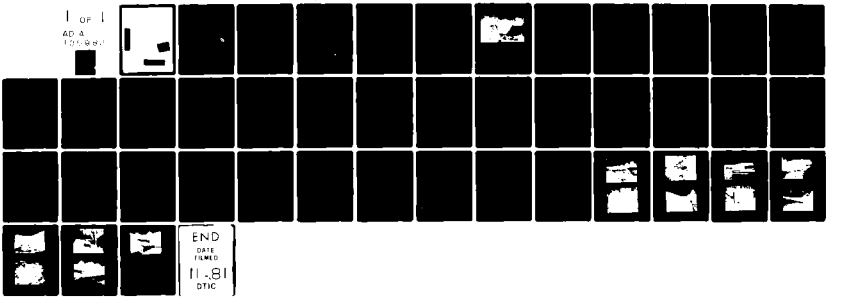

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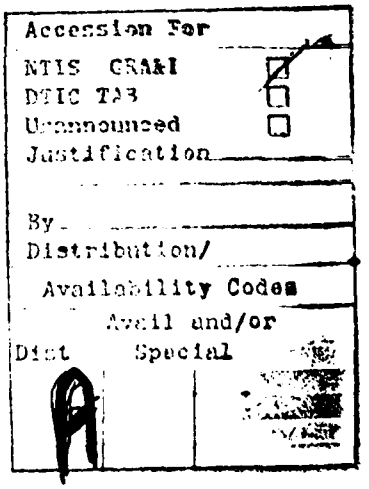
SUNNEN LAKE DAM
WASHINGTON COUNTY, MISSOURI

MISSOURI INVENTORY NO. 30111

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



PREPARED BY: ST. LOUIS DISTRICT CORPS OF ENGINEERS
FOR: GOVERNOR OF MISSOURI

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam	Sunnen Lake
State Located	Missouri
County Located	Washington County
Stream	Fourche Renault
Date of Inspection	25 August 1978

Sunnen Dam was inspected by an interdisciplinary team of engineers from the St. Louis District, U.S. Army Corps of Engineers. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual observations, in order to determine if the dam poses hazards to human life or property.

The guidelines used in the assessment were furnished by the Department of the Army, Office of the Chief of Engineers and developed with the help of several Federal and state agencies, professional engineering organizations, and private engineers. Based on these guidelines, this dam is classified as an intermediate size dam with a high downstream hazard potential. Failure would threaten the life and property of approximately six families downstream of the dam and cause appreciable damage to two unimproved roads and one county road.

For its size and hazard category, this dam is required by the guidelines to pass 100 percent of the Probable Maximum Flood (PMF) without overtopping. Analyses of the Sunnen Lake Dam indicates that overtopping will occur at 20 percent of the PMF. Since the spillway is not capable of passing even 50 percent of the PMF without overtopping the dam and perhaps causing failure, the spillway is considered seriously inadequate and the dam is accordingly considered unsafe.

Deficiencies visually observed by the inspection team were trees and brush on the dam, benching of the upstream slope, inoperative condition of outlet works, voids under the spillway apron, creep of downstream slope, and seepage. Seepage and stability analyses comparable to the requirements of the guidelines are not on record; this is also a deficiency which should be rectified.

It is recommend that the owners take action to correct or control the deficiencies described.

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Geologist
St. Louis District
Corps of Engineers

for

Richard D. Mills
PHILLIP S. EYDMANN
Hydrologic Engineer
St. Louis District
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Thomas F. Wolff
THOMAS F. WOLFF
Soils Engineer
St. Louis District
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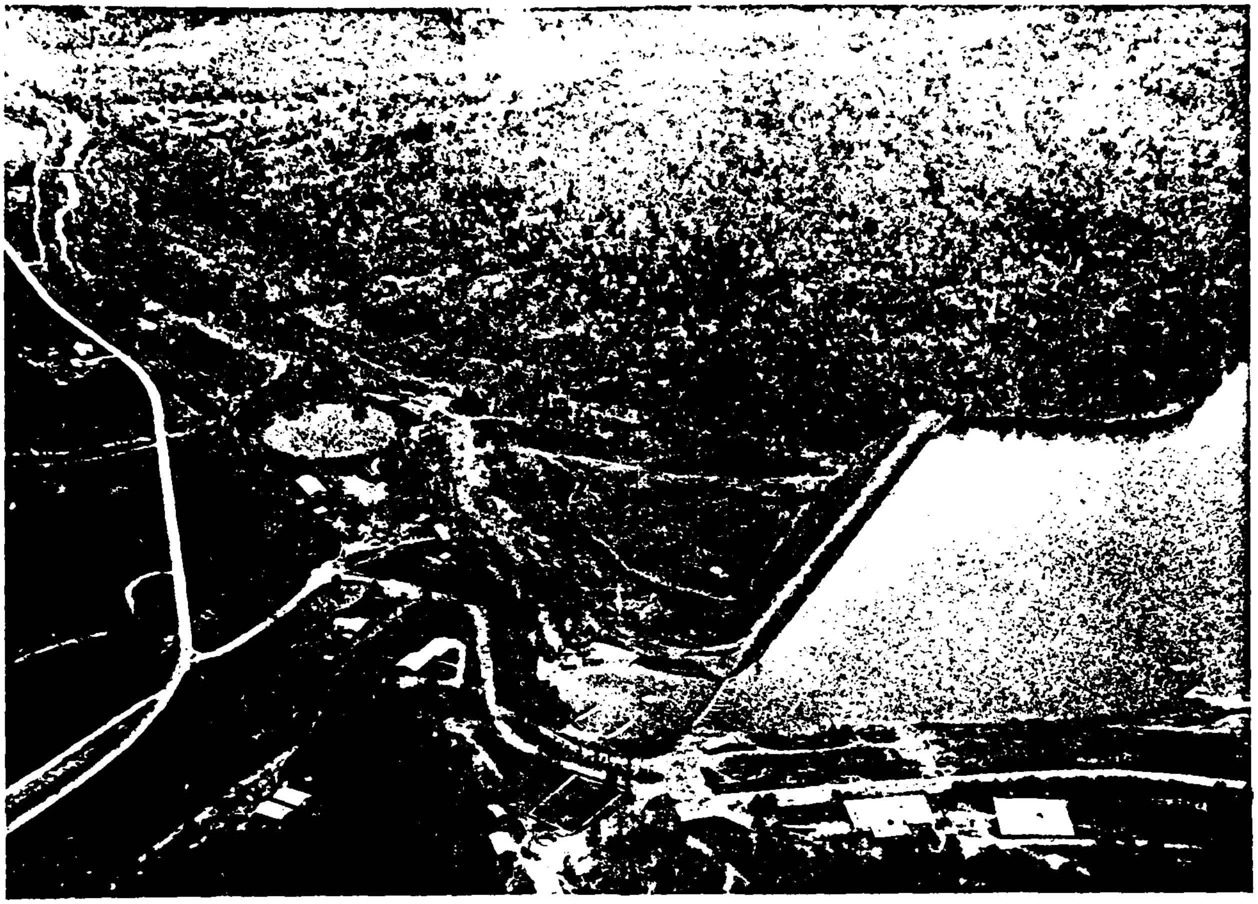
Submitted BY: _____ 29 Sept 78
Chief, Engineering Division — Date

Approved BY: _____ 29 Sep 78
Colonel, CE, District Engineer — Date



Over View of Lak[illegible] [illegible] Da[illegible]

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
SUNNEN LAKE DAM - ID NO. 30111

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
SUNNEN DAM ID NO. 30111

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, District Engineer directed that a safety inspection of the Sunnen Lake Dam be made.

b. Purpose of Inspection. The purpose of the inspection was to make an assessment of the general condition of the dam with respect to safety, based upon available data and visual inspection, in order to determine if the dam poses hazards to human life or property.

c. Evaluation Criteria. Criteria used to evaluate the dam were furnished by the Department of the Army, Office of the Chief of Engineers, in "Recommended Guidelines for Safety Inspection of Dams." These guidelines were developed with the help of several Federal agencies and many state agencies, professional engineering organizations, and private engineers.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances.

(1) The dam is an earth structure built in a narrow valley. The topography adjacent to the valley is rolling to steep. The dam was apparently constructed of red, cherty clay, which is present in the reservoir vicinity. The foundation of the dam is built on course crystalline limestone or dolomite apparently of Ordovician Gasconade formation. Topography of the lake area is shown on Plate 1.

(2) The spillway is located on the left abutment. The spillway consists of a concrete weir with a downstream concrete apron. Two 1-foot square blockouts with steel plates which may possibly be removed are located 2 feet below the weir crest; removing these plates would allow lowering the lake 2 feet. The outlet works are located near the right abutment and consist of two 48-inch reinforced concrete pipes with gates. The gates are located in a concrete box and have never been used. A steel framed tower located over the concrete box and containing the gate operators toppled due to ice in the winter of 1976-77 rendering the outlet works inoperative.

b. Location. The dam is located in the central portion of Washington County, Missouri, as shown on Plate 1. The lake formed by the dam is shown on the Missouri-Washington County Shirley Quadrangle sheet in the SE¼ of sec 4, E½ of sec 9, SW¼ of sec 10, and the NW¼ of sec 15, T37N, R1E.

c. Size Classification. Criteria for determining the size classification of dams and impoundments are presented in the guidelines referenced in paragraph 1.1c above. Based on these criteria, this dam and impoundment is in the intermediate size category.

d. Hazard Classification. Guidelines for determining hazard classification are presented in the same guidelines as referenced in paragraph 1.2c above. Based on referenced guidelines, this dam is in the high hazard classification.

e. Ownership. This dam is owned by the St. Louis YMCA, Camping Service Director, Mr. Ron W. Cook, 1528 Locust, St. Louis, Missouri 63103.

f. Purpose of Dam. The dam forms a 198-acre recreational lake.

g. Design and Construction History. The inspection team was unable to find any design data on this dam. It was reported that the dam was built in 1948. As-built drawings dated 1949 were on record and are shown on Plates 4, 5, and 6.

h. Normal Operating Procedure. The dam has an uncontrolled spillway for normal flow and two 48-inch gated outlets. The outlet works are never used and are presently inoperative.

1.3 PERTINENT DATA

a. Drainage Area - 17,182 acres.

b. Discharge at Damsite.

(1) All discharge at the damsite is through an uncontrolled spillway.

(2) Estimated experienced maximum flood at damsite - Unknown

(3) Estimated ungated spillway capacity at maximum pool elevation - 16,760 cfs.

c. Elevation (Feet Above M.S.L.). (Means sea level, referenced to assume benchmark using USGS quad sheet)

(1) Top of dam - varies/approx. 853.8 (see Plate 2 and 3).

(2) Spillway crest - varies/approx. 843.9 feet m.s.l.

(3) Streambed at centerline of dam - 804 feet m.s.l.

(4) Maximum tailwater - unknown.

d. Reservoir. Length of maximum pool - 7000 feet approx.

e. Storage (Acre-feet). Top of dam - 5,000+

f. Reservoir Surface (Acres).

(1) Top of dam - 320.

(2) Spillway crest - 198.

g. Dam.

(1) Type - Earth.

(2) Length - 1318 feet.

(3) Height - 54 feet.

(4) Top width - 24 feet.

(5) Side Slopes -

(a) Downstream - 1V on 2.0 H.

(b) Upstream - unknown, as built drawings indicate IV on 3H.

(6) Zoning - unknown, except for some details indicated on attached as built drawing (Plate 5).

(7) Impervious Core - unknown, (see 6 above).

(8) Cutoff - attached as built drawing (Plate 5) implies a cutoff was constructed. Further details unknown.

(9) Grout curtain - unknown.

h. Diversion and Regulating Tunnel.

i. Spillway.

(1) Type - Concrete.
(2) Length of weir - 184 feet.

(3) Crest elevation - 845 feet

j. Regulating Outlets. Two 48-inch reinforced concrete pipes with gates set in a concrete box. Outlet works are presently unoperable.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

No design computations are known to exist. As-built drawings dated 1949, are included as Plates 4, 5, and 6. These imply that the dam was zoned to some extent and a cutoff and downstream drain were provided.

2.2 CONSTRUCTION

The dam was constructed in approximately 1948. Mr. Joseph Sunnen of Sunnen Products Corporation and a director of the YMCA was the principal benefactor. A few construction photos were on file at the lake office but no detailed data were available. The spillway was raised about 2 feet in the mid-1950's. Outlet conduit joints were re-grouted this year (1978) based under the direction of Sverdrup and Parcel and Associates.

2.3 OPERATION

No comprehensive operating records exist. Pertinent recollections of YMCA and Sunnen personnel are included in a recent inspection report by Sverdrup & Parcel & Associates. This report was prompted by the failure of the gate tower for the outlet works. The report also was the basis for recent re-grouting of the outlet conduit joints.

2.4 EVALUATION

a. Availability. No engineering data are readily available to evaluate the design of the dam. However, a recent inspection report is on file along with a proposal for design of a new outlet tower and other remedial work. The proposal was under consideration by the owners at the time of this inspection. As-built drawings on file with the owner give general information regarding the dams construction.

b. Adequacy. Seepage and stability analyses comparable to the requirements of the guidelines are not on record. This is a deficiency which should be rectified. Surveys and visual observations made by the inspection team are considered adequate to support the conclusions reported herein.

c. Validety. Not applicable, except that it is presumed that the as built drawings are representative of the dam as originally constructed.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. Mr. Ron Cook, YMCA camping services director, accompanied the inspection team. Mr. Cook also furnished for the teams' review a recent inspection and evaluation report for the dam by Sverdrup & Parcel & Associates, consulting engineers. The consultant had inspected the dam on 14 June, 25 August, and 8 September 1977. The submerged outlet box containing the outlet gates was inspected by diver and videotape. At the time of the consultants inspection, the east conduit was leaking 0.2 cfs and the west conduit 1.7 cfs. Some of the leakage was reported to be entering the pipe joints as close as 40 feet from the outlet, although the main leakage was occurring from the gate box. The consultant directed a program of grouting the pipe joints and leaks which has significantly reduced leakage. The consultants' other findings and recommendations were essentially similar to those in this report and involved placement of upstream riprap, monitoring surface creep, monitoring of the marshy area at the toe, and patching of the spillway. The owners are presently considering a proposal by the consultant for design of a concrete gatewell to replace the sunken gate tower and other remedial measures.

b. Project Geology.

(1) Sunnen Lake and Dam is located at the northern edge of a graben of flat lying Paleozoic rock downdropped between the Shirley fault zone to the north and the Palmer fault system to the south. Two isolated knobs of Precambrian felsite porphyry flanked by Cambrian Potosi dolomite are located within 3 miles of the dam. The upper elevation around the reservoir consists of the Ordovician Roubidoux sandstone. This is underlained by approximately 250 feet of Ordovician Gasconade dolomite, and beneath that the Cambrian Eminence dolomite.

(2) The damsite foundation consists of weathered pinnacles of grey, dense, medium-grained dolomite of the Eminence formation located downstream of the spillway on the left abutment at approximate elevation 820 feet msl. A small solution cavity (3 feet x 2 feet entrance, extending back about 2 feet) was observed at the water level 50 feet downstream of the spillway. This was the only clear evidence of solution activity found in the damsite area. A small cave is said to be present in an adjacent valley some distance from the damsite.

(3) The right abutment near the toe of the dam is composed of medium to thickly bedded, light grey, fine-grained dolomite with fingers of chert overlain by a 2-foot bed of fine white dense chert

of the Gasconade formation. The foundation contains few measurable joints; those measured were northwest-southeast in orientation. The beds dip approximately 4 degrees to the southeast. The exposed outcrops are relatively unfractured; the slopes above the outcrop are composed of chert float with no in-place rock which is typical of slopes in the Gasconade formation. Continuous outcropping of this Gasconade dolomite was followed for over 1,000 feet along the reservoir rim.

(4) Below the dam on the right abutment and directly beneath the previous outcrop is a massive, bedded, unjointed, grey, medium to fine-grained chert free dolomite of the Eminence formation. A small amount of water was found seeping from an irregular horizontal bedding plane, approximately elevation 840 feet msl, separating the two formations.

(5) An abandoned lead mining area consisting of several small pits, a filled shaft, and talus slope is located approximately 1,500 feet southeast of the left abutment. Immediately north of this area evidence of faulting was found; however, neither the orientation nor offset could be determined.

(6) The Shirley fault zone is located 3,000 feet north of the dam and can be seen in the roadcuts along Highway AA. At this location the fault strikes northwest-southeast and is displaced from 200 to 400 feet, downdropped on the southwest. The fault has been described as extending for 8 miles as a zone consisting of several faults all stepped down to the southwest. The last major movement along this fault has been described as being post-Ordovician (440 million years before present) and it is not considered to be active. No evidence of leakage problems from the lake was found associated with this fault. Although this inspection failed to reveal the presence of any faulting in the immediate dam abutments, the nature and proximity of this fault zone to the dam, coupled with the presence of the faulted and mineralized area 1,500 feet to the southeast, suggest that other minor faulting is present in the damsite area.

c. Dams.

(1) No detrimental cracking, settlement, sinkholes, or slides were observed in the embankment. Embankment cross-sections shown in Plates 2 and 3 are typical. Downstream slopes are relatively steep for a dam of this height, as evidenced by slow soil creep or sloughing along the portions of the slope. One-inch pipes were driven into the embankment in the mid-1950's, reportedly to retard the creep; the pipes are now sloping at various, in some cases extreme, angles. Some disruption of the pipes by pedestrian or horse traffic is also apparent. The steepness of the downstream slope

also inhibits slope maintenance. Despite the steepness and localized creep, the embankment appears to be stable against a general, shear-type sliding failure based on its 30 years of satisfactory performance.

(2) Thick brush and scattered trees are present on the embankment. These root systems constitute a potential seepage hazard and the brush provides animal habitat which increases the likelihood of animal burrows. Hoof prints were also prevalent on portions of the embankment; a bridle path is present along the toe. Horse traffic has removed grass cover in localized areas.

(3) The upstream face of the dam has no riprap or other wave protection of any kind. Wave action has eroded a bench (vertical face above a horizontal face) as much as 5 feet high along the entire dam. Wave action could be expected to be a problem at this lake because of its long narrow shape and north-south orientation with the dam at the north end. The dam's wide crown and relatively high freeboard has prevented wave erosion to date from being a serious safety threat.

(4) A clear seep, flowing 1 gpm or less, was found in the right abutment. This appears to be a spring from the rock abutment, whose discharge level is kept high by influence of the adjacent pool. Some iron oxide staining was noted. A marshy area containing cattails 6 feet high was noted downstream of the dam toe near the middle of the dam's length. The marshy conditions occur over an area about 40 feet by 100 feet with the cattails occurring over only a portion of the marsh. Seepage is occurring as evidenced by conditions, but without perceptible flow. Both the abutment seep and the downstream marsh area have been reportedly present for many years without significant change. The marsh area was reported to be present before construction but of a lesser extent.

d. Appurtenant Structures.

(1) The spillway consists of a concrete weir with a downstream concrete apron. The concrete apron provides a trapezoidal outlet channel transitioning to a rock outlet channel. The concrete weir was raised about 2 feet in the 1950's and, therefore, not in agreement with the as-built drawings (Plate 4). Two 1-foot square blockouts with steel plates, possibly removalable, are located 2 feet below the weir crest; removing these plates would allow lowering the lake 2 feet.

(2) Spillway concrete was generally in good condition with no structural cracking. Surface spalling was present in several locations and the slab on the right of the apron just below the weir had extensive surface cracking which apparently had been repaired with a white grout.

(3) At either side of the lower end of the spillway, where the apron slab had been placed on and around large boulders, pieces of the concrete were missing, exposing voids between and under the boulders. In the void to the right of the spillway, a 4-inch clay pipe, apparently part of a slab underdrain system, was discharging 1 to 2 gpm into the void. At the end of the concrete apron, it could be seen that a significant fraction of the spillway flow was coming under the apron.

(4) The outlet works consists of two 48-inch diameter reinforced concrete pipes, each 280 feet long and comprised of 4-foot sections. The gates are located in an underwater concrete gate box and have never been used. A steel tower containing the gate operators had toppled due to ice and could not be seen. The west pipe which had previously flowed 1.7 cfs (765 gpm) was flowing less than 1 gpm and flow in the east pipe could barely be detected. A short length of the interior of both pipes was inspected from the downstream end and the recent joint grouting could be seen. The greatly diminished flow indicates that recent grouting has been effective. The consulting engineer's inspection report indicated that the east gate was in good condition with only surface rust, but that the west gate was severely rusted.

e. Reservoir Area. No wave wash, excessive erosion or slides were observed along the shore of the reservoir.

f. Downstream Channel. Erosion was noted at the downstream end of the spillway. Trees and vegetation were presented in both the spillway and outlet channels.

3.2 EVALUATION

Brush and small trees on the embankment, lack of erosion protection on the upstream face, benching of the upstream face, and present inaccessability and inoperable condition of outlet gates are deficiencies which should be corrected. Steepness of the dam's slopes inhibit routine maintenance and are a factor in creep or sloughing of the downstream face. The slope creep, gate leakage, abutment seepage, and marshy conditions at the dam toe are not presently of a serious nature but should be carefully monitored for any change. Spalling concrete in the spillway should be patched. Voids under the spillway apron should be filled and any pipes or other water flow therein directed out from under the slab. Continued flow of water under the slab could further undermine the slab and endanger its performance where needed to pass large flows. Horse traffic on dam prevents establishment of turf and induces erosion. The tie-in embankment between the spillway and main dam lacks erosion protection and may be inadequate to resist a sustained high spillway flow.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The dam has an uncontrolled spillway for normal flow and hence no detailed operational procedures are required. As discussed in the previous sections, the outlet works is never used and is presently inoperative.

4.2 MAINTENANCE OF DAM

Maintenance has been performed occasionally, as evidenced by lack of large trees on the embankment. However, routine maintenance such as brush and small tree removal on the embankment is not apparent.

4.3 MAINTENANCE OF OPERATING FACILITIES

Lack of maintenance dewatering facilities in the gatebox and the fact that the lake has never been drained indicates that little if any maintenance of the outlet gates has been possible. The outlet conduit joints have recently been grouted.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

No warning system is known to exist. Operating personnel are on the site year-round and could contact authorities in an emergency.

4.5 EVALUATION

Additional maintenance in the form of removing brush and small trees is recommended. When the gate tower is repaired, it should be of a type that will allow removal of the gates for inspection and maintenance.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. No design data was made available to the inspection team. All releases are made over a spillway located at the western most edge of the structure. A low level outlet works with gatebox was located at the eastern side of the dam but the gatebox has deteriorated and is in need of replacement. Future plans reportedly are being made to replace this structure. Until then all water must flow over the spillway.

b. Experience Data. All pertinent data furnished in this report were based on computations derived from either USGS 7-1/2-minute quardrangle sheets or measurements and surveys made during the field inspection.

c. Visual Observations.

(1) The spillway structure appeared to be sound and debris free.

(2) Erosion was present at the lower downstream end of the spillway structure on both east and west sides.

(3) Exit channels of the spillway and outlet pipes had trees and vegetation overgrown throughout. Some sediment deposition was noted in channels which could allow additional overgrowth problems.

(4) Some very minor concrete spalling on downstream face.

d. Hydrologic and Hydraulic Analysis Methodology.

(1) The hydrologic analysis used in development of the overtopping potential is applying a hypothetical storm to a unit hydrograph to obtain the inflow hydrograph for a reservoir routing. The Probable Maximum Precipitation is derived and determined from regional charts prepared by the National Weather Service in "Hydrometeorological Report No. 33." Reduction factors have not been applied. A 24-hour storm duration is assumed with total depth distribted over 6-hour periods in accordance with procedures outlined in EM 1110-2--1411 (SPF Determination). The maximum 6-hour rainfall period is then distributed to hourly increments by the same criteria. Within-the-hour distribution is based upon NOAA Technical Memorandum NWS HYDRO-35. The non-peak 6-hour rainfall periods are distributed uniformly. All distributed values are arranged in a critical sequence by the SPF criteria. The final inflow hydrograph is produced by deduction of infiltration losses appropriate to the soil, land use, and antecedent moisture conditions.

(2) The reservoir routing is accomplished by using Modified Puls routing technicques wherein the flood hydrograph is routed through lake storage. Hydraulic capacities of the spillway and crest of dam are used as outlet controls in the routing. Storage in the pool area is defined by an evaluation was capacity curve and storage calculated by the conic method. The hydraulic capacity of the outlet works, spillway, and top of dam are defined by evaluation-discharge curves.

(3) Dam overtopping analysis has been conducted by hydrologic methods for this dam and lake. This computation determines the percentage of the PMF hydrograph that the reservoir can contain without the dam being overtopped. An output summary in the hydrologic appendix displays this information as well as other characteristics of the simulated dam overtopping.

(4) The overtopping analysis has been accomplished for this report using the systemized computer program HEC-1 (Dam Safety Version), July 1978, prepared by the Hydrologic Engineering Center, U. S. Army Corps of Engineers, Davis, California. The numeric parameters estimated for this site are listed in Appendix A. Definitions of these variables are contained in the "User's Manual" for the computer program.

e. Overtopping Potential. The Sunnen Lake Dam can be overtopped by any flood greater than 20 percent of the Probable Maximum Flood (PMF). The PMF is defined as the flood discharge that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably in the region. Sunnen Lake Dam can be overtopped by a 1 percent chance flood. A 1 percent chance flood is a flood with a 1 percent chance of being exceeded in any given year. The guidelines require that a dam of this hazard potential (high) and size pass 100 percent of the PMF without overtopping the dam. The maximum discharge over the dam for 100 percent of the PMF is 105,626 cfs. The maximum depth of flow over the low point of the earth embankment by 100 percent of the PMF is 7.8 feet. The duration of overtopping is 7.3 hours. Since the spillway for Sunnen Lake Dam is not even capable of passing at least 50 percent of the PMF without overtopping the dam, and may cause failure, the spillway is considered seriously inadequate and the dam is accordingly considered unsafe.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. No evidence of structural instability was noted at the spillway or outlet pipes. The outlet control box was underwater and could not be inspected but had recently been inspected by a diver for the owner's engineer. For further discussion of the visual observations, see Section 3.

b. Design and Construction Data. See Section 2. No design data were found but as-built drawings obtained from the owner are shown as Plates 4, 5, and 6.

c. Operating Records. See Section 4.

d. Post Construction Changes. The spillway was raised about 2 feet in the mid-1950's. Outlet pipe joints have recently been grouted and construction of a new gate tower is presently under consideration.

e. Seismic Stability. The dam is located in seismic zone 2, for which the recommended guidelines assign a "moderate" damage probability. Since detailed information on the properties of the materials in the embankment is not available, an accurate seismic evaluation cannot be made. The clayey materials used in the embankment minimize the likelihood of failure due to earthquake.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety.

(1) Several items are deficient which should be corrected. No erosion protection is present on the upstream face of the embankment and wave action has caused benching along the length of the embankment. Brush and small trees are growing on the embankment. Horse traffic on the embankment has removed grass in localized areas. Voids under the spillway apron could lead to undermining. The outlet works is presently inoperable.

(2) Seepage from the abutment, seepage in a marshy area at the toe, and surface creep of the downstream slope, are items not presently endangering the dam but should be carefully monitored for changing conditions.

(3) The spillway is not adequately sized to pass the Probable Maximum Flood.

b. Adequacy of Information. The statements and recommendations in this report are based on visual observations and verbal discussions. Seepage and stability analyses comparable to the requirements of the guidelines are not on record this is a deficiency which should be rectified. Findings and recommendations of this report are generally consistent with those of the owner's consulting engineer based on a detailed inspection in 1977.

c. Urgency. We recommend the remedial measures listed in Section 7.2 be accomplished in the near future.

d. Necessity for Phase II. A Phase II inspection is not recommended. Action should begin on the remedial actions discussed in this report.

7.2 REMEDIAL MEASURES

The following remedial measures are recommended:

a. Remove trees and cut brush and establish turf in horse-damaged areas.

b. Restrict horse traffic from the embankment, or surface bridle trails.

c. Provide adequate erosion protection such as riprap on the upstream face of the dam. Repair benching of the embankment.

d. An engineer should perform seepage and stability analyses comparable to the requirements of the guidelines.

e. Construct an outlet facility which will allow the outlet gates to be operated and maintained.

f. Fill voids under spillway and re-direct water discharging under the spillway apron.

g. Monitor abutment seepage, creep of the downstream slope, and the marshy area at the toe for any change from present conditions.

h. Continue to have a periodic inspection by an engineer experienced in the design and construction of dams as was done recently. Maintain records of these inspections and maintenance actions.

i. The spillway size and/or height of the dam should be increased to pass the Probable Maximum Flood without overtopping the dam.

APPENDIX A

HYDROLOGIC COMPUTATIONS

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NOTICE TO HEC1DB USERS

 12 SEP ... FOR THE DIVERSION OPTION,
 THE DEFAULT VALUE OF DVRMx IS NOW 0.0 (ZERO).
 THE MAXIMUM VOLUME (ACRE-FT) OF DIVERTED FLOW CAN BE
 SPECIFIED IN FIELD 6 OF THE + CARD.  THIS OPTION IS NOT
 USED IF FIELD 6 IS LEFT BLANK OR ZERO.

 21 AUG ... A TABLE AND PLOT OF THE BREACH HYDROGRAPH
 HAVE BEEN ADDED TO HELP CHECK VALIDITY OF DOWNSTREAM
 CALCULATIONS.

  1 AUG ... THE MAXIMUM NUMBER OF HYDROGRAPH ORDINATES
 HAS BEEN INCREASED TO 300.  MEMORY REQUIREMENTS ARE
    LBL,  SFL,153000,116000.
    BCS,  CM350000 ON JOB CARD

  1 AUG ... INITIAL WATER SURFACE ELEVATION CAN BE
 SPECIFIED FOR MODIFIED PULS ROUTING.  SET STORA ON THE
 Y1 CARD TO BE THE NEGATIVE OF THE INITIAL ELEVATION.
 THE PROGRAM INTERPOLATES INITIAL STORAGE FROM STAGE-FLOW
 AND STORAGE-OUTFLOW CURVES.

 FOR TECHNICAL ASSISTANCE CONTACT
 ARLEN FELDMAN, JOHN PETERS, OR PAUL ELY
 AT THE HYDROLOGIC ENGINEERING CENTER
 916-440-2329 (FTS 448-2329)
1**********
 FLOOD HYDROGRAPH PACKAGE (HEC-1)
 DAM SAFETY VERSION      JULY 1978
   LAST MODIFICATION  12 SEP 78
 **********
     1                A  ***** PHILLIP S. EYDMANN  **   DAM SAFETY REPORT *****
     2                A  ***** SUNNEN DAM  ********** COST CODE = EL                ***
     3                A *****                                 *****
     4                B    140        0       20        0        0        0        0        0        0        0
     5                B1     5
     6                J      1        5        1
     7                J1   .15      0.2      .25      0.5      1.0
     8                K      0        1                                  3        1
     9                1 ***** INFLOW HYDROGRAPH COMPUTATION *****
    10                M      1        2     26.8                      1.00                             1
    11                P             26.5       96      112      120      132
    12                T                                                        -1     -.82                .05
    13                M2             1.4        0
    14                X   10.0     -.02      1.5
    15                K      1     DAM1                                 2        2        1
    16                1 ***** RESERVOIR ROUTING BY MODIFIED PULS *****
    17                Y                                      1        1
    18                Y1     1                                                 2699       -1
    19                Y4  843.9    845.0    846.0    848.0    850.0    852.0    854.0
    20                Y5    0.0    540.0   1530.0   4320.0   7930.0  12220.0  17100.0
    21                $A      0      198      326      627      971
    22                $F    803    843.9      860      880      900
    23                $$ 843.9
    24                $D 853.8      2.7      1.5     1200
    25                K     20
                                  PRINTOUT OF SEQUENCE OF STREAM NETWORK CALCULATIONS
```

ROUTE HYDROGRAPH TO DAM1
END OF NETWORK

1**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 12 SEP 78
****

RUN DATE= 78/09/20.
TIME= 08.07.31.

***** PHILLIP B. EYDMANN ** DAM SAFETY REPORT *****
***** SUNNEN DAM ********** COST CODE = EL ***
***** *****

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
144	0	20	0	0	0	0	0	0	0
			JOPER	NWT	LROPT	TRACE			
			5	0	0	0			

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 5 LRTIO= 1
RTIOS= .15 .20 .25 .50 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

***** INFLOW HYDROGRAPH COMPUTATION *****

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	0	0	0	3	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	2	26.80	0.00	26.80	1.00	0.000	0	1	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.00	26.50	96.00	112.00	120.00	132.00	0.00	0.00

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0	0.00	0.00	1.00	0.00	0.00	1.00	-1.00	-82.00	0.00	.05

CURVE NO = -82.00 WETNESS = -1.00 EFFECT CN = 82.00

UNIT HYDROGRAPH DATA
TC= 0.00 LAG= 1.40

UNIT HYDROGRAPH 23 END OF PERIOD ORDINATES, TC= 0.00 HOURS, LAG= 1.40 VOL= 1.00

922. 2901. 5963. 7942. 8215. 7246. 5710. 3791. 2667. 1930.
1363. 962. 679. 474. 336. 238. 169. 119. 87. 66.
45. 26. 9.

0 END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.20	1	.00	.00	.00	10.	1.02	.20	73	.05	.04	.01	357.
1.01	.40	2	.00	.00	.00	10.	1.02	.40	74	.05	.04	.01	428.
1.01	1.00	3	.00	.00	.00	11.	1.02	1.00	75	.05	.04	.01	620.
1.01	1.20	4	.00	.00	.00	13.	1.02	1.20	76	.05	.04	.01	879.
1.01	1.40	5	.00	.00	.00	14.	1.02	1.40	77	.05	.04	.01	1149.
1.01	2.00	6	.00	.00	.00	16.	1.02	2.00	78	.05	.04	.01	1389.
1.01	2.20	7	.00	.00	.00	17.	1.02	2.20	79	.05	.04	.01	1581.
1.01	2.40	8	.00	.00	.00	17.	1.02	2.40	80	.05	.04	.01	1710.
1.01	3.00	9	.00	.00	.00	18.	1.02	3.00	81	.05	.04	.01	1804.
1.01	3.20	10	.00	.00	.00	18.	1.02	3.20	82	.05	.04	.01	1873.
1.01	3.40	11	.00	.00	.00	18.	1.02	3.40	83	.05	.04	.01	1925.
1.01	4.00	12	.00	.00	.00	18.	1.02	4.00	84	.05	.04	.01	1963.
1.01	4.20	13	.00	.00	.00	18.	1.02	4.20	85	.05	.04	.01	1992.
1.01	4.40	14	.00	.00	.00	18.	1.02	4.40	86	.05	.04	.01	2014.
1.01	5.00	15	.00	.00	.00	17.	1.02	5.00	87	.05	.04	.01	2032.
1.01	5.20	16	.00	.00	.00	17.	1.02	5.20	88	.05	.04	.01	2046.
1.01	5.40	17	.00	.00	.00	17.	1.02	5.40	89	.05	.04	.01	2058.
1.01	6.00	18	.00	.00	.00	17.	1.02	6.00	90	.05	.04	.01	2068.
1.01	6.20	19	.02	.00	.02	18.	1.02	6.20	91	.24	.20	.03	2228.
1.01	6.40	20	.02	.00	.02	20.	1.02	6.40	92	.24	.21	.03	2714.
1.01	7.00	21	.02	.00	.02	26.	1.02	7.00	93	.24	.21	.03	3707.
1.01	7.20	22	.02	.00	.02	33.	1.02	7.20	94	.24	.21	.02	5035.
1.01	7.40	23	.02	.00	.02	41.	1.02	7.40	95	.24	.21	.02	6423.
1.01	8.00	24	.02	.00	.02	47.	1.02	8.00	96	.24	.21	.02	7667.
1.01	8.20	25	.02	.00	.02	52.	1.02	8.20	97	.24	.22	.02	8669.
1.01	8.40	26	.02	.00	.02	56.	1.02	8.40	98	.24	.22	.02	9362.
1.01	9.00	27	.02	.00	.02	58.	1.02	9.00	99	.24	.22	.02	9873.
1.01	9.20	28	.02	.00	.02	60.	1.02	9.20	100	.24	.22	.02	10262.
1.01	9.40	29	.02	.00	.02	61.	1.02	9.40	101	.24	.22	.02	10555.
1.01	10.00	30	.02	.00	.02	62.	1.02	10.00	102	.24	.22	.01	10778.
1.01	10.20	31	.02	.00	.02	62.	1.02	10.20	103	.24	.22	.01	10952.
1.01	10.40	32	.02	.00	.02	63.	1.02	10.40	104	.24	.22	.01	11088.
1.01	11.00	33	.02	.00	.02	63.	1.02	11.00	105	.24	.22	.01	11197.
1.01	11.20	34	.02	.00	.02	63.	1.02	11.20	106	.24	.22	.01	11286.
1.01	11.40	35	.02	.00	.02	64.	1.02	11.40	107	.24	.22	.01	11360.
1.01	12.00	36	.02	.00	.02	68.	1.02	12.00	108	.24	.22	.01	11422.
1.01	12.20	37	.08	.01	.07	82.	1.02	12.20	109	.85	.81	.04	12018.
1.01	12.40	38	.08	.02	.07	123.	1.02	12.40	110	.85	.82	.03	13773.
1.01	13.00	39	.09	.02	.06	208.	1.02	13.00	111	.85	.82	.03	17334.
1.01	13.20	40	.10	.03	.07	344.	1.02	13.20	112	1.02	.99	.03	22228.
1.01	13.40	41	.10	.04	.07	530.	1.02	13.40	113	1.02	.99	.02	27634.
1.01	14.00	42	.10	.04	.06	759.	1.02	14.00	114	1.02	1.00	.02	33000.
1.01	14.20	43	.13	.06	.07	1029.	1.02	14.20	115	1.27	1.25	.02	38040.
1.01	14.40	44	.13	.06	.06	1331.	1.02	14.40	116	1.27	1.25	.02	42504.
1.01	15.00	45	.13	.07	.06	1672.	1.02	15.00	117	1.27	1.26	.02	46915.
1.01	15.20	46	.22	.13	.09	2089.	1.02	15.20	118	2.22	2.20	.02	52000.
1.01	15.40	47	.61	.41	.20	2870.	1.02	15.40	119	6.09	6.04	.05	61905.
1.01	16.00	48	.14	.10	.04	4061.	1.02	16.00	120	1.35	1.35	.01	77294.
[illegible]													

1.01	17.20	52	.09	.07	.02	6746.	1.02	17.20	124	.93	.93	.00	102589.
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1.01	18.20	55	.01	.01	.00	5099.	1.02	18.20	127	.07	.07	.00	71303.
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1.01	22.00	66	.01	.01	.00	484.	1.02	22.00	138	.07	.07	.00	6155.
1.01	22.20	67	.01	.01	.00	427.	1.02	22.20	139	.07	.07	.00	5385.
1.01	22.40	68	.01	.01	.00	386.	1.02	22.40	140	.07	.07	.00	4825.
1.01	23.00	69	.01	.01	.00	355.	1.02	23.00	141	.07	.07	.00	4409.
1.01	23.20	70	.01	.01	.00	335.	1.02	23.20	142	.07	.07	.00	4137.
1.01	23.40	71	.01	.01	.00	322.	1.02	23.40	143	.07	.07	.00	3974.
1.02	0.00	72	.01	.01	.00	313.	1.03	0.00	144	.07	.07	.00	3860.
									SUM	34.98	32.60	2.38	1672156.
										(888.)(	828.)(	60.)(47350.18)	

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	108704.	66524.	22062.	11599.	1670219.
CMS	3078.	1884.	625.	328.	47295.
INCHES		23.09	30.63	32.21	32.21
MM		586.51	778.02	818.07	818.07
AC-FT		32987.	43759.	46012.	46012.
THOUS CU M		40689.	53976.	56754.	56754.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 1

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	16306.	9979.	3309.	1740.	250533.
CMS	462.	283.	94.	49.	7094.
INCHES		3.46	4.59	4.83	4.83
MM		87.98	116.70	122.71	122.71
AC-FT		4948.	6564.	6902.	6902.
THOUS CU M		6103.	8096.	8513.	8513.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 2

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	21741.	13305.	4412.	2320.	334044.
CMS	616.	377.	125.	66.	9459.
INCHES		4.62	6.13	6.44	6.44
MM		117.30	155.60	163.61	163.61
AC-FT		6597.	8752.	9202.	9202.
THOUS CU M		8138.	10795.	11351.	11351.

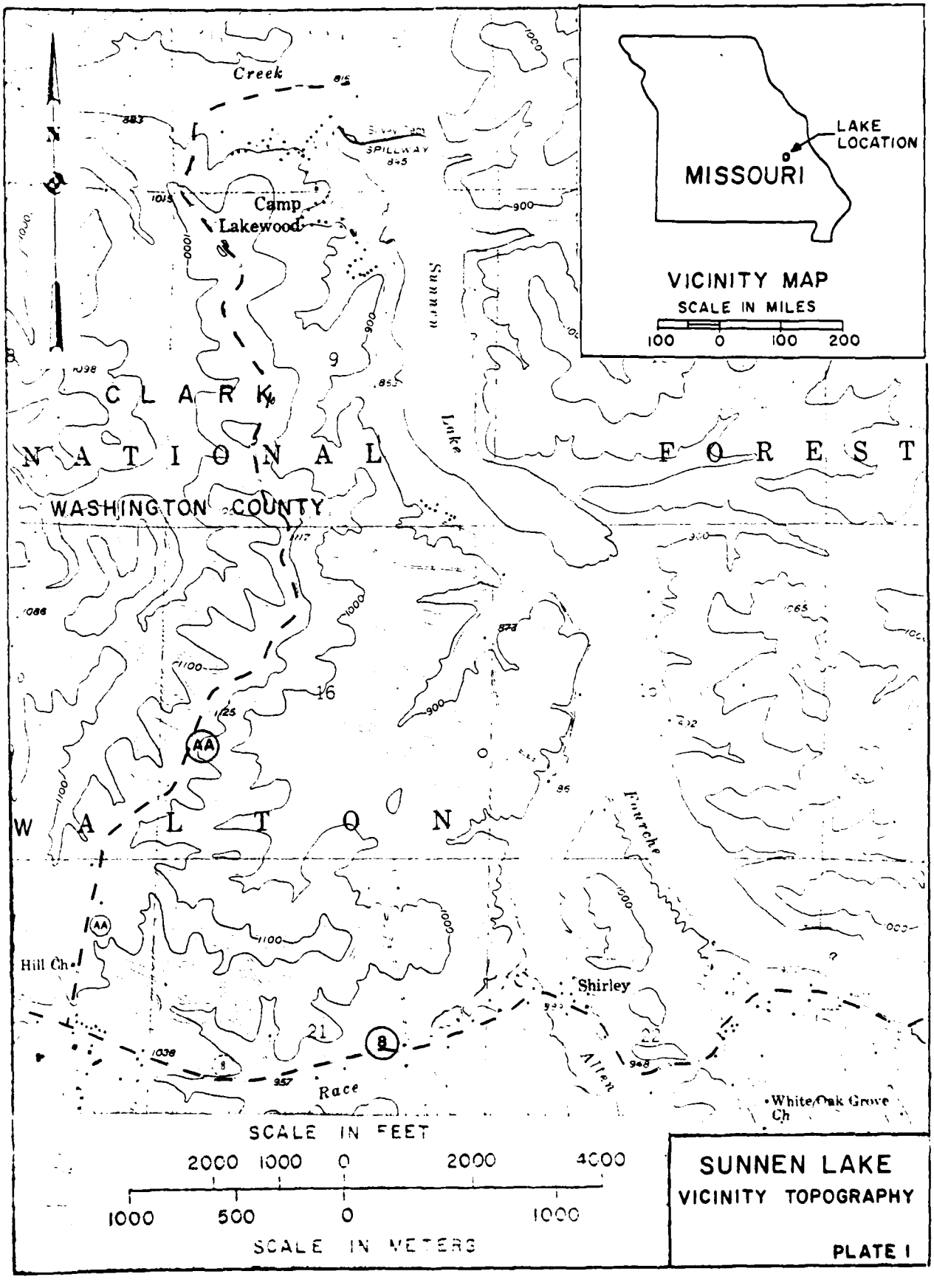
SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	843.89	843.90	853.80
STORAGE	2698.	2699.	5021.
OUTFLOW	0.	0.	16761.

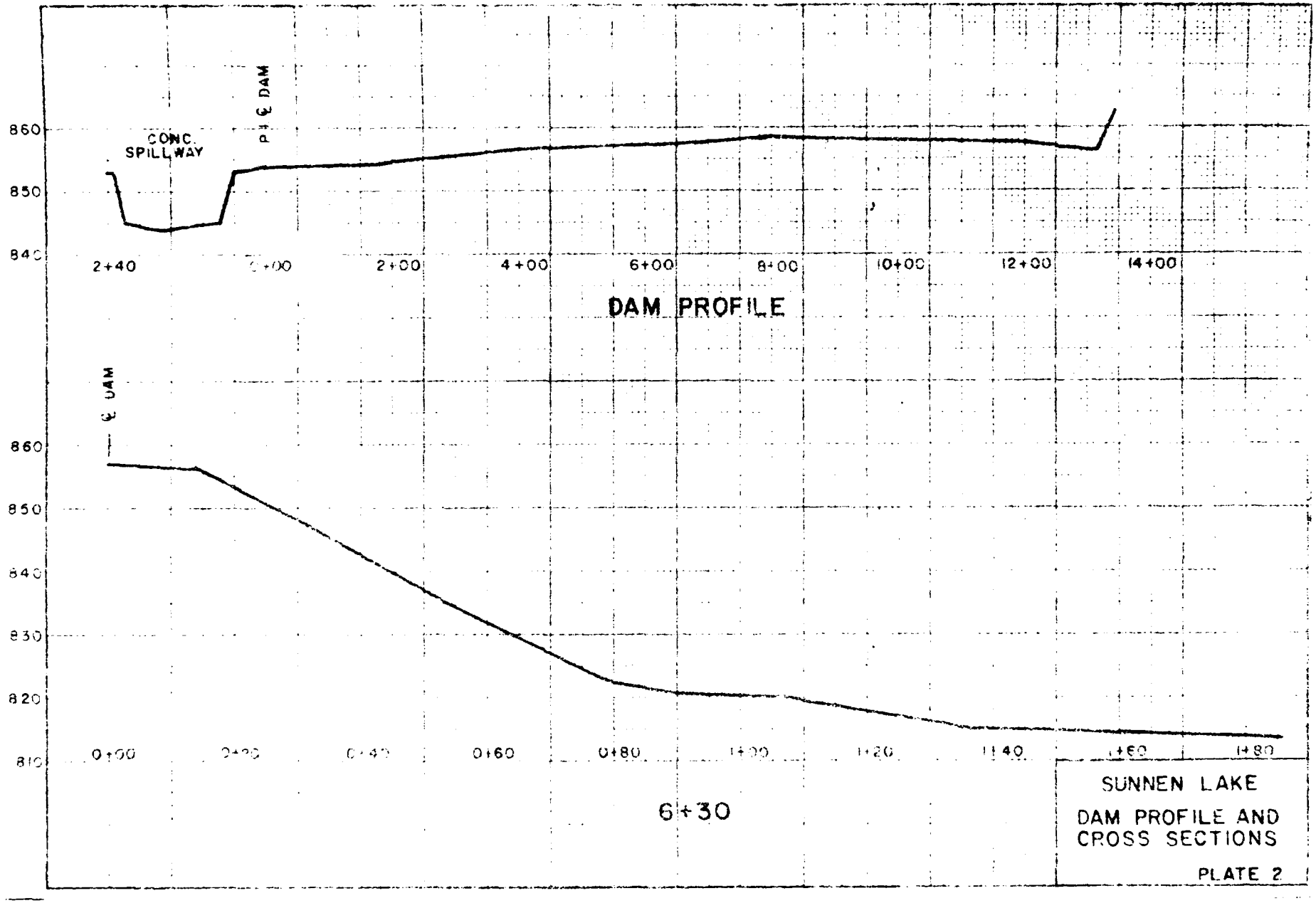
RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.15	852.08	0.00	4562.	12689.	0.00	42.00	0.00
.20	853.90	.10	5048.	16968.	.67	42.00	0.00
.25	855.03	1.23	5362.	23850.	2.33	41.67	0.00
.50	857.87	4.07	6199.	52521.	5.00	41.33	0.00
1.00	861.63	7.83	7424.	105626.	7.33	41.33	0.00

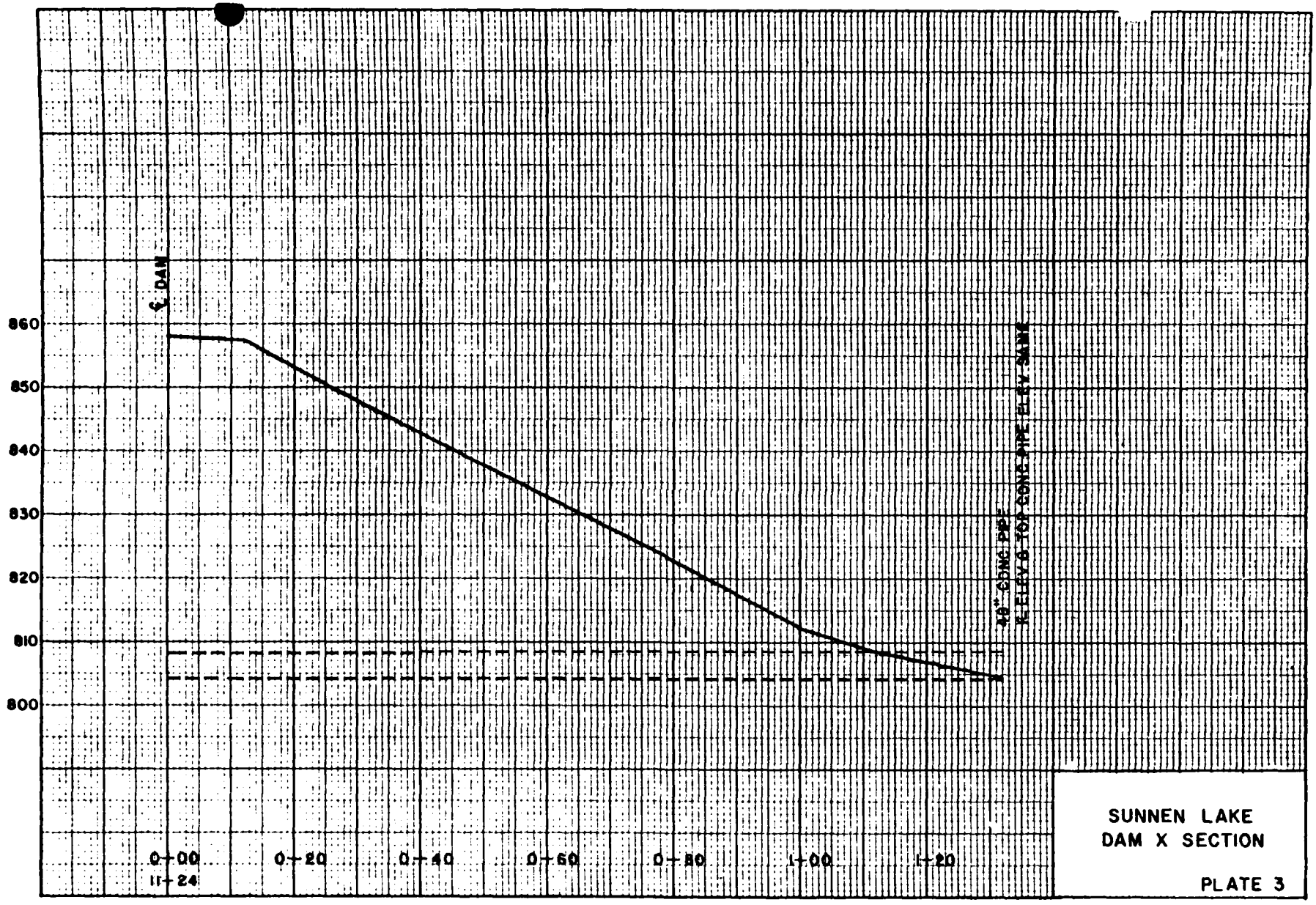
1**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 12 SEP 78
****



SUNNEN LAKE
VICINITY TOPOGRAPHY

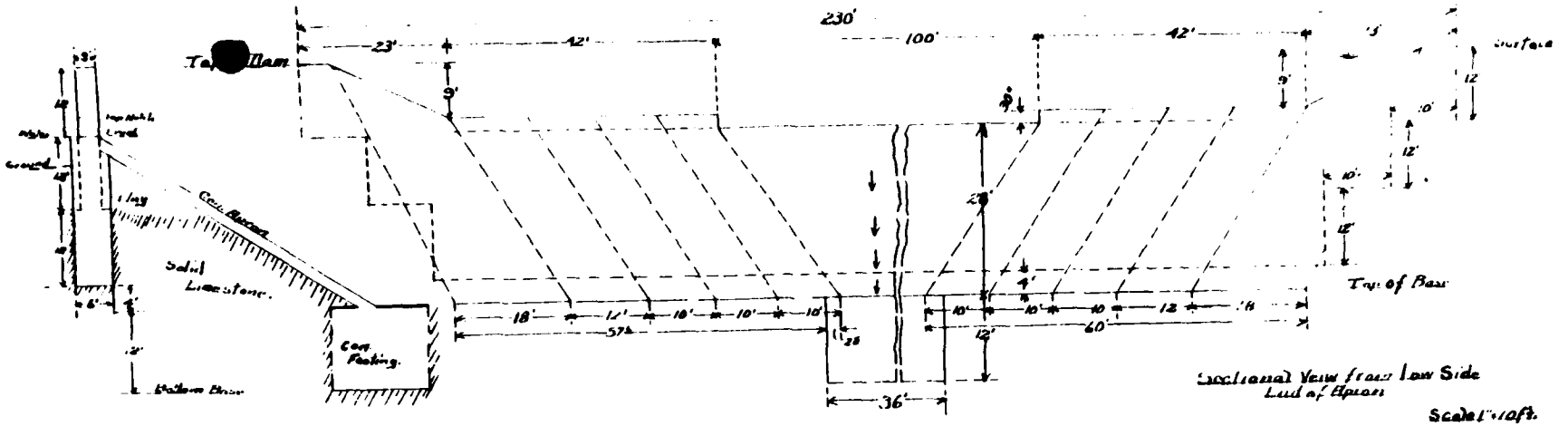
PLATE I


CONC. SPILLWAY
℄ DAM
860
850
840
2+40
2+00
4+00
6+00
8+00
10+00
12+00
14+00
DAM PROFILE
℄ DAM
860
850
840
830
820
810
0+00
0+40
0+60
0+80
1+40
1+80
6+30
SUNNEN LAKE
DAM PROFILE AND
CROSS SECTIONS
PLATE 2



SUNNEN LAKE
DAM X SECTION

PLATE 3

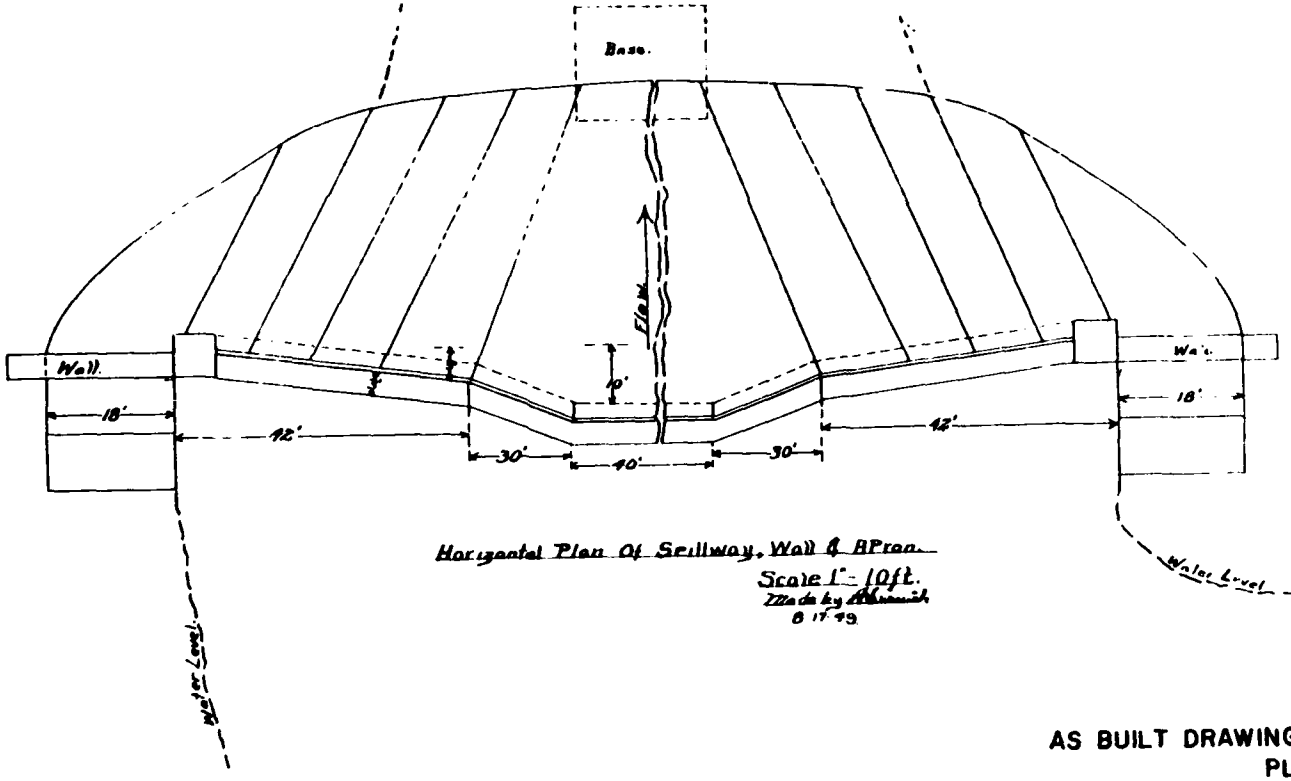


Sectional View from low Side Lead of Apron

Scale 1" = 10 ft.

X Section on ℄ Dam

Sheet No 3.



Horizontal Plan Of Spillway, Wall & APron.

Scale 1" = 10ft.

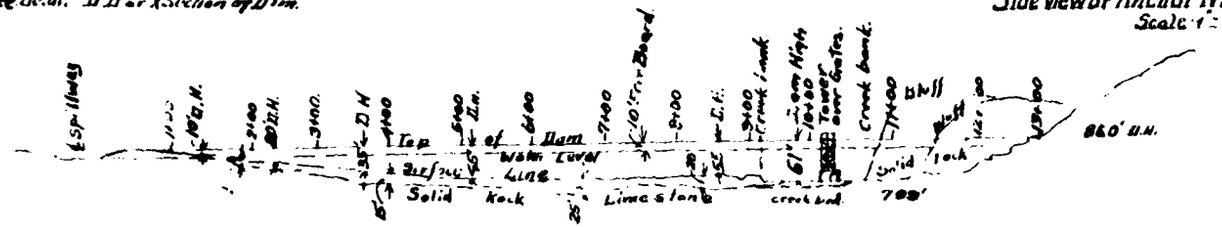
Made by [illegible] Smith

8 IV 99

AS BUILT DRAWING
PLATE 4

Material Used in Sec C C was Gravel for Drainage
Material Used in Sec D-D was A No1
Good Compaction Clay with Poorer
Grade on back Side with Medium or Better
on front Side of Dam.
See Detail B B or X Section of Dam.

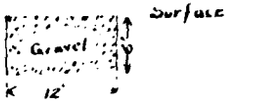
Side View of Anchor Wall at B B.
Scale 1" = 1ft



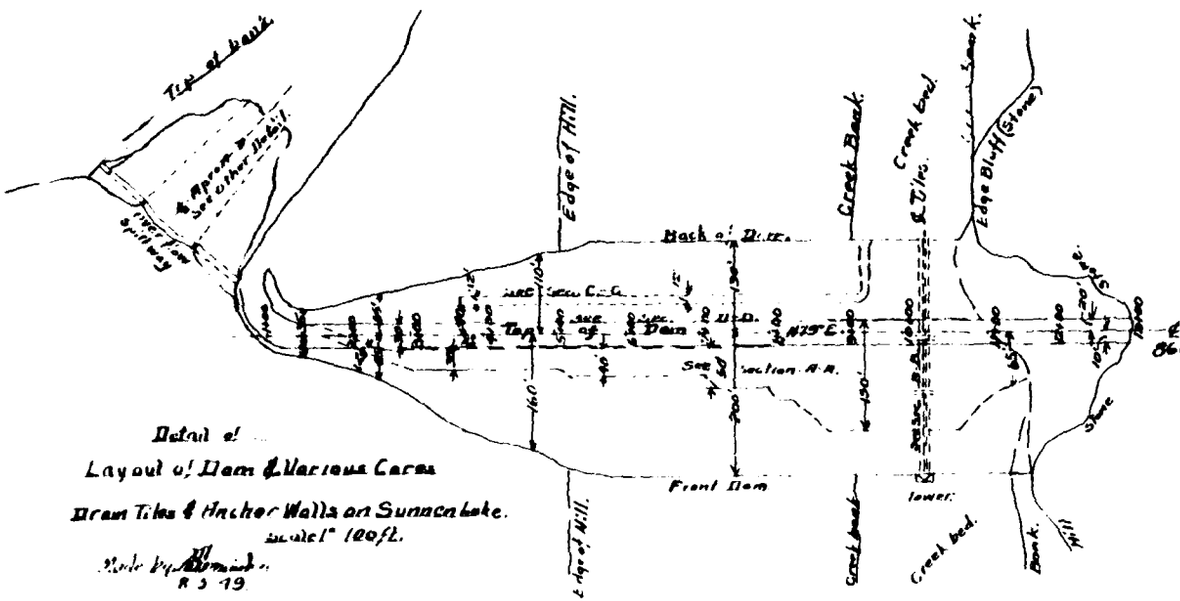
Section B B or X Sec of Dam Top
Scale 1" 100ft

Side Plan of Front of Dam, Spillway & Bluff on East End.

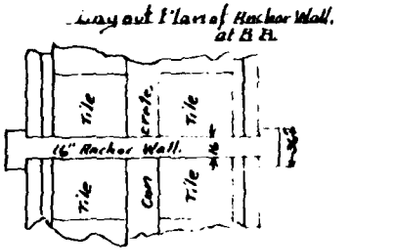
Scale 1"=100'
Sheet No 1

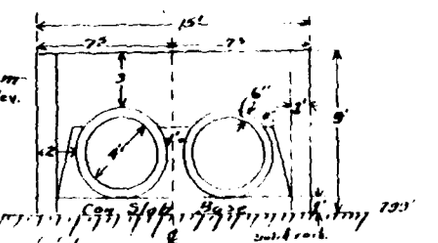


Sec C C or Drainage Ditch
Scale 1/4" = 1'-0"



Detail of
Layout of Dam & Various Cases
Drain Tiles & Anchor Walls on Sunnen Lake.
Scale 1" 100 ft.
Made by [redacted]
R S 19





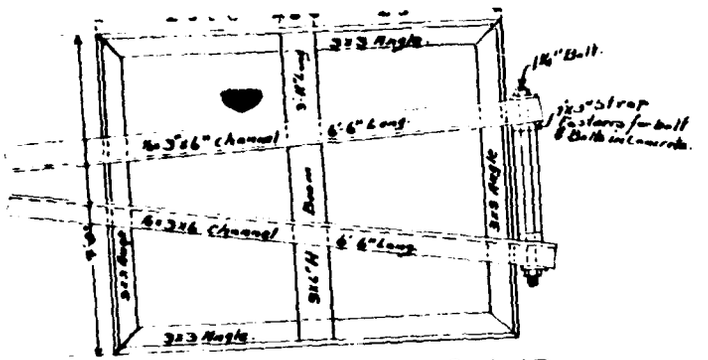
Sec B B at Anchor Wall
Scale 1/4"=1'-0"

AS BUILT DRAWING
PLATE 5

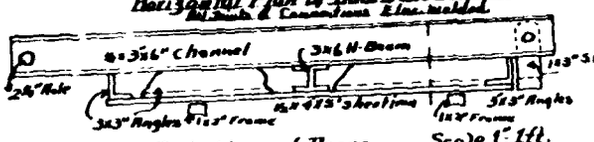
Sheet No 2.

Detail of Tower & Gates & Doors of Control Box

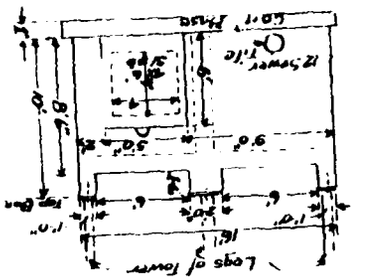
Made by
L.P. Kenwith
8-24-19.



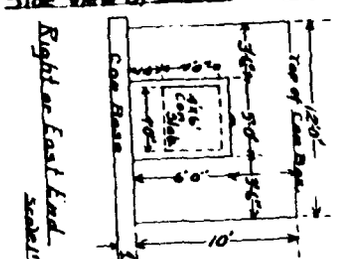
Horizontal Plan of Doors on Control Box



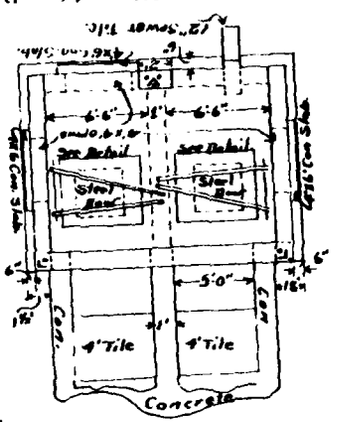
Side View of Doors. Scale 1" 1ft

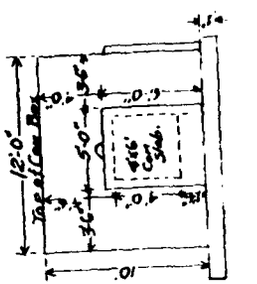


Horizontal Plan of Con. Box & Tile. Scale 1" 5ft

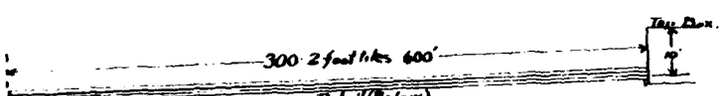


Right or East End. Scale 1" 5ft

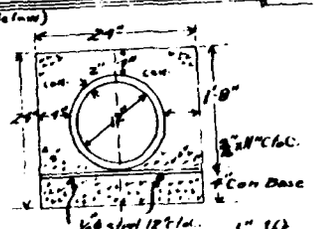




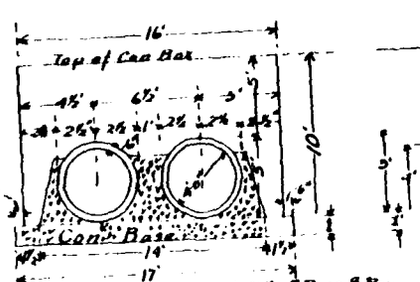
West or Left End



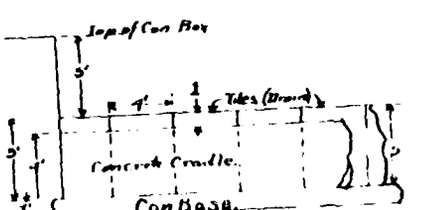
Note:-
Concrete base under Sewer line was placed upon any type material as gravel, sand, muck, hard or soft clay surface. Not trenched only when needed to maintain grade line. Fills not computed. Approx grade 25° 2 ft.



Detail of Sewer line



Back Elevation of Tile & Base & Box



Side Elevation of Cradled Tile 1"-5ft.

AS BUILT DRAWING
PLATE 6

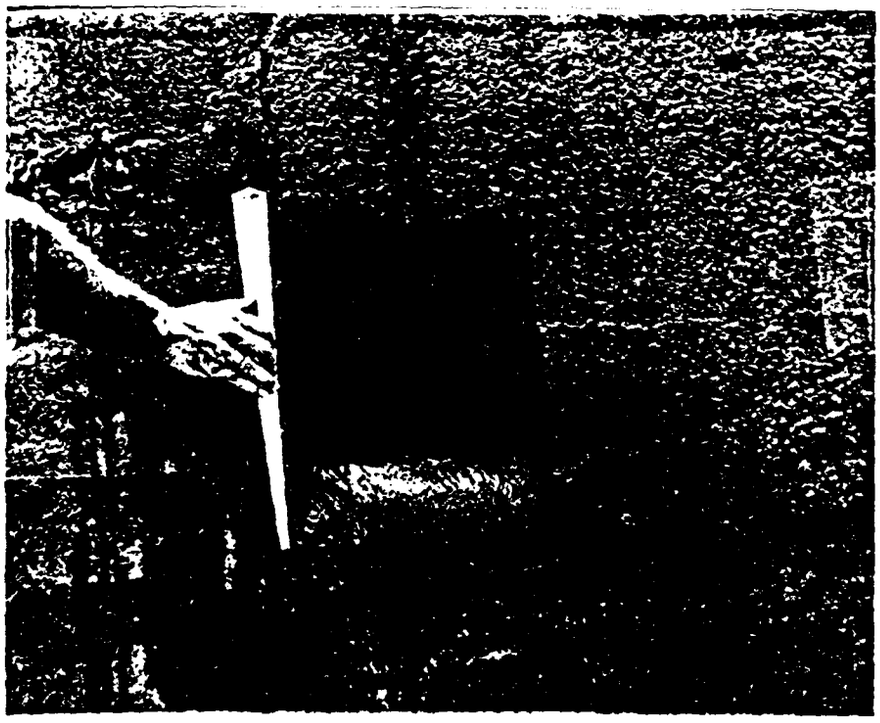
1 Spillway

2 Marshy Area at Toe

3 Outlet Pipes

4 Downstream Slope

5 Overview

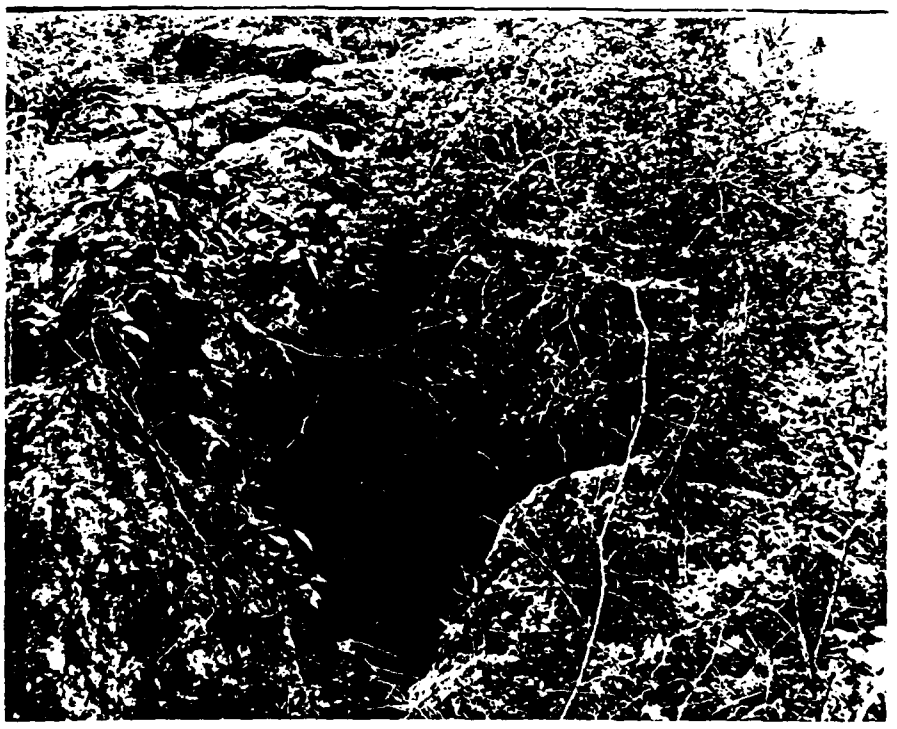


6 Spillway Blockout

7 Spillway Outlet Channel

8 Upstream Slope

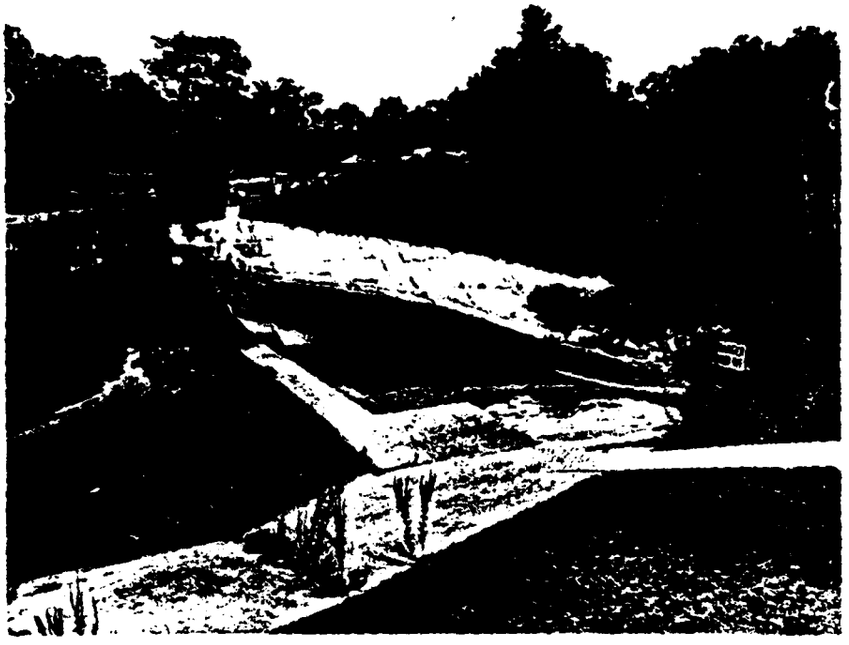
9 Outlet Channel



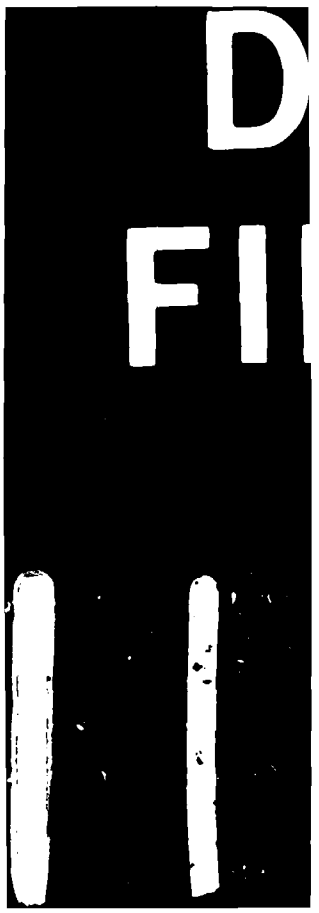
10 Roid in Spillway

11 Benching in Upstream Slope

12 Spillway



13 Spillway and Outlet Channel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